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LA-UR--87-3591

DE88 001797

TITLE THE DESIGN OF AN ISOTOPE SEPARATION SYSTEM FOR JET

AUTHOR(S) Robert H. Sherman
Tritium Science and Technology Group
Materials Science and Technology Division
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

SUBMITTED TO IEEE 12th Symposium on Fusion Engineering
Monterey, California
October 12-16, 1987

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Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

THE DESIGN OF THE DEHAZER PLANT FOR DIII-D

R. L. BROWN
T. R. HARRIS
J. C. KELLY
C. A. ROBERTS
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Abstract

The design of the dehaizer plant for the deuterium-tritium plasma fueling system of the DIII-D tokamak is described. The dehaizer plant is required to remove the deuterium and tritium impurities from the deuterium-tritium fuel gas which will be used to fuel the DIII-D plasma. The dehaizer plant must also remove the helium and hydrogen which will be released by the plasma during deuterium-tritium fusion.

Introduction

The dehaizer plant will be required to handle deuterium and tritium later phases of plasma to present some interesting problems in the design of a two-phase separation system.

The dehaizer plant separates the deuterium and tritium from the deuterium-tritium fuel assembly. Two separate deuterium and tritium streams, with 100% purity requirements, and a neutral beam injector running in a continuous cycle, will, on the other hand, plan for the eventuality of D_2 and T_2 neutral beams and D_2 and T_2 pellet injector operating simultaneously.

In Table I, the various dehaizer fuel streams for the DIII-D two-phase separation plant are summarized. Feed stream #1 results from the pellet injector when it uses H_2 as a propellant for either D_2 or T_2 pellets. The second stream is a combination of torus exhaust and neutral beam exhaust streams. The feed streams originate from the fuel reprocessing system Active Ion Handling System which receives the various exhaust streams during operation and, after thorough cleaning, processes them to remove impurities, and then supplies them to a central feed bus to the dehaizer. In addition, there are four feed streams which represent different operating modes of gas recharging neutrality conditions.

The design of the dehaizer plant for the DIII-D is discussed in another paper at this conference.

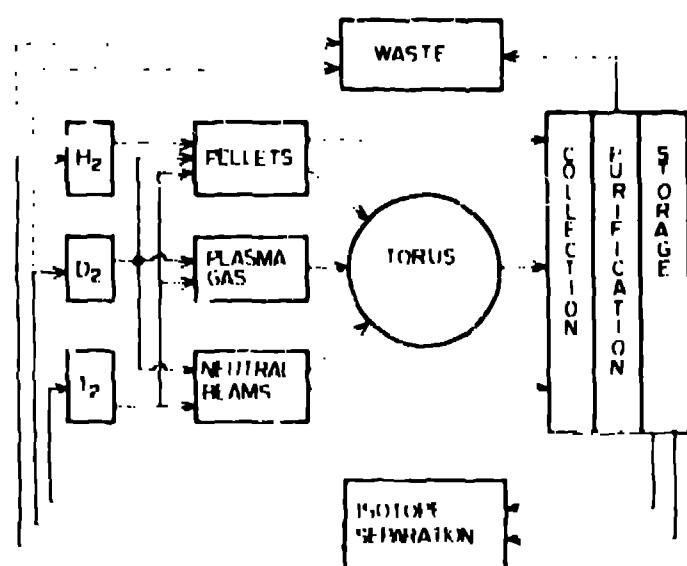


Fig. 1. Dehaizer Fuel Flow Path for DIII-D

Table I

Stream	Description	Feed	Rate	Product
1	Deuterium	Pellet	100%	Deuterium
2	Deuterium	Neutral Beam	100%	Deuterium
3	Hydrogen	Pellet	100%	Hydrogen
4	Hydrogen	Neutral Beam	100%	Hydrogen
5	Deuterium	Exhaust	100%	Deuterium
6	Hydrogen	Exhaust	100%	Hydrogen
7	Deuterium	Reprocessing	100%	Deuterium
8	Hydrogen	Reprocessing	100%	Hydrogen

In Table II, the output fuel stream requirements of the dehaizer plant are given. These, in general, are easily met by the use of dehaizer cryogenic distillation as the primary means of effecting two-phase separation of D-T fuel. However, both the D_2 and T_2 product streams, as well as the D_2 and T_2 product streams are dehaized, rather than recycled. A more stringent set of product purity requirements must be met, which are given in Table III.

Table II

Dehaizer output fuel stream requirements for Product Recovery

Dehaizer	Dehaizer	Product
1	100%	Deuterium
2	100%	Deuterium
3	100%	Hydrogen
4	100%	Hydrogen
5	100%	Deuterium
6	100%	Hydrogen
7	100%	Deuterium
8	100%	Hydrogen

Table III

Dehaizer output fuel stream requirements with Product Recovery & Assumptions

Dehaizer	Dehaizer	Product
1	100%	Deuterium
2	100%	Deuterium
3	100%	Hydrogen
4	100%	Hydrogen
5	100%	Deuterium
6	100%	Hydrogen
7	100%	Deuterium
8	100%	Hydrogen

Note that fuel flow streams are indicated in Fig. 1.

It is possible to arrive at a wide variety of plant designs to accomplish the stream purity requirements. Three of these will be discussed below.

Design

The basic principles for dehaizing and the general dehaizer plant for the separation of hydrogen isotopes have been outlined in an earlier paper (1). In the situation considered here, we are presented with the following assumptions: (1) the 99.99% isotopic mixture and deionized, very pure products of H_2 , D_2 and T_2 ; hence, a complete separation of H_2 , D_2 and T_2 must be accomplished. The use of a large internal cycle stream of H_2 such as used at JETA for decompressing D_2 into H_2 and D_2 will not work here. Instead, a system of several cascaded columns with recycle will always must be employed to deplete these species.

Scheme

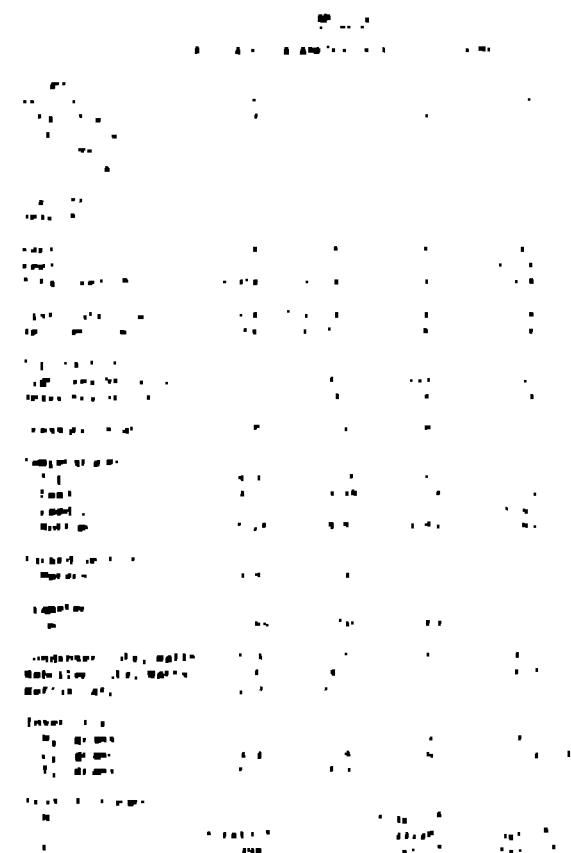
In the first run, some short equilibrium runs of 100 sec. were made at each of the stations. The results are given in Table I. Spectra of the output from stations A and B, 10 and 12, are obtained at the different frequencies of 100 sec. These are then fed into the last oscillator and the 100 sec. stream thus obtained is fed into the second detector. It operates like the first detector and gives two outputs, one at 10 sec. and 12 sec. The ratio of these two outputs is measured and from it the ratio of the two currents in the second detector is obtained.

The next day, the two men were still at the station, but the train had not yet arrived.

Based on the results of the present study, it appears that the tritium species, which were the most abundant in the environment, had the greatest influence on the growth of the plants. The presence of tritium in the environment may have contributed to the observed increase in the growth of the plants. The tritium species can be detected at the highest detection limit level.

while R_1 and R_2 can be kept at their by-product product volumes to any desired levels, such as not the case with R_3 . Essentially all of the first two columns of R will appear as a commitment in the by-product. Thus the only money it requires is if R_3 or column B is the most restricted factor in overall product purity. This capacity may be increased by increasing the number of stages per unit of the reflux ratio (retention power), but at the expense of increased capital investment.

The base design parameters for the 1000 kg class using the nominal feed system of Table 1 are summarized in Table 11. Table 11 includes the base design values for the feed system and the resultant design parameters are given similarly.



```

graph LR
    E1((E1)) --> A[A]
    A --> E2((E2))
    E3((E3)) --> B[B]
    B --> E4((E4))
    E5((E5)) --> C[C]
    C --> E6((E6))
    E7((E7)) --> D[D]
    D --> E8((E8))

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Fig. 1. First, second, and third

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A different technique was employed by A. Domke [3] and his detailed design, completed by A. Everett, J. Yetter and A. Miller, is as shown in Fig. 1.

In this scheme there are two separate recycle loops, each having its own pump. The unreacted species in the recycle loops are then brought together through the mixing stage. In addition, a pump is used for the

the first time in 1935, and has continued through 1936. This is the first time that the Bureau has been able to make a definite statement that the Bureau's work is being done in accordance with the law.

the first time in the history of the world, the people of the United States have been compelled to make a choice between two political parties, each of which has a distinct and well-defined platform, and each of which has a definite and well-defined object in view.

At the top of the hill the rocky patterns prepared for cultivation have the following names given by Salter. The plantations such as *Arachis*, *Purshia* and *Celtis* River where the entire slope is bare. In which there are cultivated and rearing in the bottom of the next ridge, above, of *Acacia*, *Lindernia*, *Calochortus*,

The important design parameters for this scheme are given in Table 3.

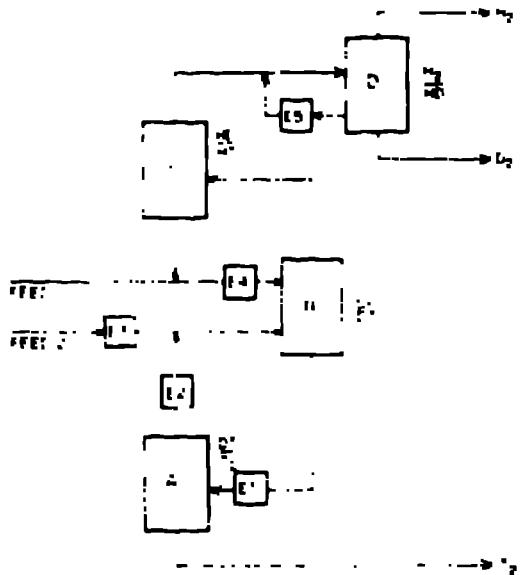


Fig. 3 Second Separation Scheme

TABLE 2					
A - 5000-COMPOUND SYSTEM - 4000					
OVERALL					
Total Stages	1	2	3	4	
Rectifying Intermediate Stripping	-	-	-	-	
Light Key Heavy Key	L	H	D	H	
Feed 1	0.0000	0.0000	0.0000	0.0000	
Feed 2	0.0000	0.0000	0.0000	0.0000	
Total Feed, moles	0.0000	0.0000	0.0000	0.0000	
Distillate 1	0.0000	0.0000	0.0000	0.0000	
Bottoms 1	0.0000	0.0000	0.0000	0.0000	
Top Fraction	0.0	0.0	0.0	0.0	
Light Key Recovery (%)	0.0	0.0	0.0	0.0	
Heavy Key Recovery (%)	0.0	0.0	0.0	0.0	
Product Recovery	0.0	0.0	0.0	0.0	
Temperature					
Top	0.0	0.0	0.0	0.0	
Bottom	0.0	0.0	0.0	0.0	
Pressure					
Atmospheric	0.0	0.0	0.0	0.0	
Atmospheric at 100% Recovery of each component	0.0	0.0	0.0	0.0	
Components					
H ₂ (grams)	0.0	0.0	0.0	0.0	
H ₂ (mole)	0.0	0.0	0.0	0.0	
D ₂ (grams)	0.0	0.0	0.0	0.0	
D ₂ (mole)	0.0	0.0	0.0	0.0	
Product Stream					
H ₂	0.0000	0.0000	0.0000	0.0000	
H ₂	0.0000	0.0000	0.0000	0.0000	
D ₂	0.0000	0.0000	0.0000	0.0000	
D ₂	0.0000	0.0000	0.0000	0.0000	

Scheme 3

A third possible configuration of 4 columns has been proposed by Arthur Little, Inc. An uncopyrighted design is illustrated in Fig. 6. Columns A and B perform just as in Schemes 1 and 2. Column C and D form a simple recycle loop in which both H₂ and D₂ are decomposed. As in Scheme 1, meeting the criterion for residual ketone in the D₂ product stream is the most difficult design problem. And here too, columns may be made arbitrarily large, but at the expense of Tritium inventory.

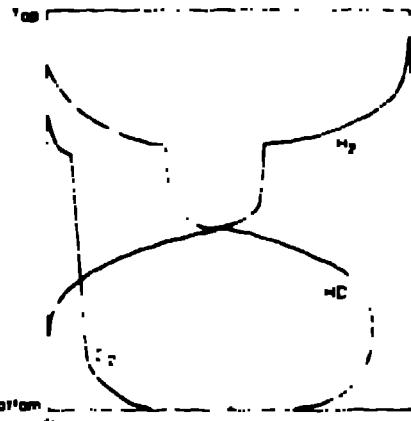


Fig. 4 Typical Three-component Profile

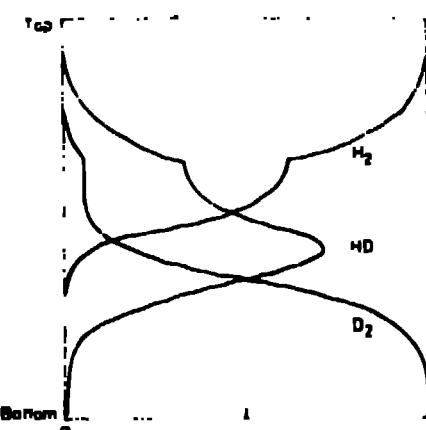


Fig. 5 Modification of Profile from Sidestream Extraction and Equilibration

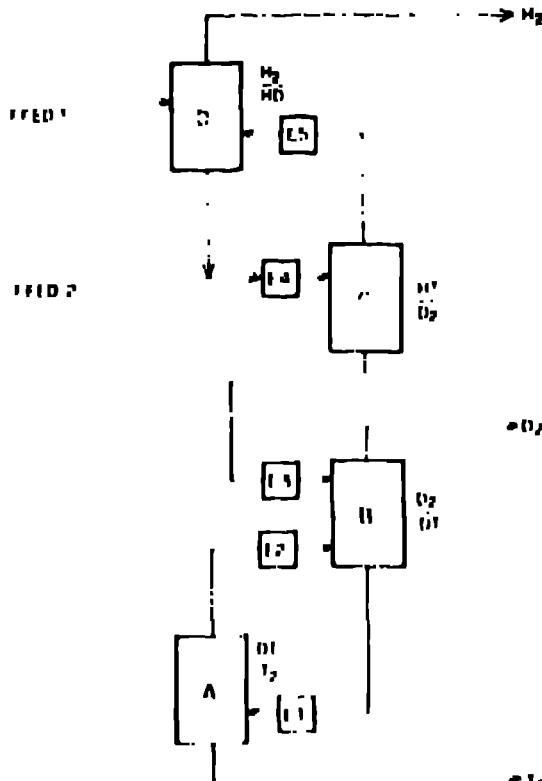


Fig. 6 Four-column Scheme of Arthur Little, Inc. (C)

TABLE VI
PARAMETERS FOR ARTHUR D. LITTLE, INC. SCHEME

SCHEME	A	B	C	D
PERCENTURE	100	100	100	100
FEED FLOW RATE	1.25	1.25	1.25	1.25
FEED CONC.	1.04	1.04	1.04	1.04
REFLUX	1.04	1.04	1.04	1.04
REFLUX CONC.	1.04	1.04	1.04	1.04
REFLUX FLOW RATE	1.25	1.25	1.25	1.25
INVENTORIES	100	100	100	100
DETECTION LIMIT	1.04	1.04	1.04	1.04
DETECTION TIME	100	100	100	100

Control.

Typical industrial processes endeavour to operate at a steady state whereas the JET operating scenario calls for many changes in feed stream concentration. While these may be damped to some degree by the Active Gas Handling System, major fluctuations will occur and it is to be expected that about 10 hours will be necessary to approach a steady state. Therefore, stability and ease of control of the isotope separation system must be of major concern to JET.

A drawback of scheme 1 lies in the control of the system. As both the PT and HT recycle loops feed into column B, an upset in either loop will induce an upset in the other loop. This can significantly increase the time to steady state after a change in operating condition.

The first scheme is also subject to these same reservations but to a lesser degree since the recycle flows are smaller.

The third scheme is by far the easiest to control since both of the recycle loops are effectively decoupled and well established control procedures may be utilized. The trade off is a somewhat larger tritium inventory.

Presently, gas chromatography is preferred analytical method of many cryogenic distillation systems. This is due to an unsatisfactory method of use of the null hour meter technique related to obtain the reading. More rapid techniques, such as Raman spectroscopy, must be employed to achieve adequate system stability.

References:

1. "The JET Active Gas Handling System - Concept and Status" IAEA International Symposium on Fusion Engineering, Paper 100, 1981, H. Hemmer et al.
2. "Private Communication - Definition for the Tritium Fuel Cycle" Fusion Technology, 9, 177-183, 1982 - R H Sherman.
3. "Private Communications" - A Nombra.
4. "Cryogenic System 4 : Isotope Separation Systems Design for JET" Report TTF-N-4, August 1987. This is an unpublished report with the source of copies being "Scientific Document Distribution Office", Atomic Energy of Canada Limited, Chalk River, Ontario, K0J 1J0 - A E Everett, V Goyette and A L Miller.
- 5/ "Private Communication - Copyrighted design" E. L. Field, Arthur D. Little, Inc.